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Economic Evaluation of Directional Drilling for Methane Drainage From Coalbeds

By E. C. Baker, D. C. Oyler, John H. Perry, and G. L. Finfinger

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

bbl	barrel	lb	pound
ft	foot	lb/ft	pound per foot
ft^3	cubic foot	m	meter
ft^3/d	cubic foot per day	M ft^3	thousand cubic feet
ft^3/h	cubic foot per hour	mi/d	mile per day
gal/d	gallon per day	mi/g	mile per gallon
gal/min	gallon per minute	$MMft^3/d$	million cubic feet per day
h	hour	pct	percent
h/d	hour per day	psig	pound per square inch, gauge
hp	horsepower	V	volt
h/yr	hour per year	W	watt
in	inch	yr	year
kW•h	kilowatt hour		

ECONOMIC EVALUATION OF DIRECTIONAL DRILLING FOR METHANE DRAINAGE FROM COALBEDS

By E. C. Baker,[1] D. C. Oyler,[2] John H. Perry,[3] and G. L. Finfinger[4]

ABSTRACT

The Bureau of Mines estimated the economic feasibility of investing in a directional hole methane drainage project in the Pittsburgh coalbed for 5 yr in advance of mining. This report estimates the capital investment and operating cost of recovering 325 $MMft^3$ of methane gas per year and the selling price of approximately 317 $MMft^3$ of gas per year.

The labor, equipment, and supply requirements were determined from those of a previous directional hole drilled at the Emerald Mine, near Waynesburg, PA. The cost of equipment, materials, services, and labor are in third quarter 1982 dollars. They were obtained from vendors, contractors, and the U.S. Department of Labor.

Findings indicate a total capital investment of $1,381,160. Annual operating cost amounted to $167,690. At a wellhead price of $2.05 per thousand cubic feet, the sale of approximately 317 $MMft^3$ of gas per year results in a rate of return on investment of approximately 25 pct.

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INTRODUCTION

As the depth of a coalbed increases, the volume of methane contained within the coal also increases. Consequently, the problems in production and maintaining a safe environment increases. However, if the methane in deeper, gassier mines could be removed economically before mining, both production and safety could be improved. The Bureau has pioneered the following three methods for degasifying coalbeds, all of which have proven to be technically feasible:

1. Vertical wells (5, 10-11).[5]

2. Horizontal hole (2, 7-9).

3. Directional drilling (1, 6-7).

Hopefully this report will serve as a guide for determining the economic feasibility of recovering methane gas by directional drilling in advance of coal mining.

The items costed in this report are based on the drilling of a directional hole at the Emerald Mine near Waynesburg, PA. The estimates of gas production are based on quantities that are proved to be obtainable by the drilling of horizontal holes. However, little gas has been produced from the Emerald Mine directional hole because of caving of the horizontal holes drilled in shale near the bottom of the casing. The problem of caving of the horizontal holes could be avoided in future directional hole drilling by insuring that the casing is inserted into the coalbed.

ASSUMPTIONS

The following assumptions were made to assist in the preparation of the capital requirements, operating cost schedules, and the economic analysis.

1. Four months predrilling preparation and 7 months (210 days) drilling time would be required prior to gas production.

2. Methane would be recovered for 347 days for each year of the 5-yr life of the drainage operation.

3. Methane gas would be compressed to 30 psig to access a gas transmission feeder system.

4. The compressor would use approximately 22,000 ft^3/d of the total 937,000 ft^3 of gas produced daily.

5. The producing company would own coal and gas rights.

6. Predrilling equipment and services would be purchased by the gas producing company.

7. Directional drilling labor, equipment, supplies, and services would be contracted.

8. Equity capital would be used to finance the project.

9. Five-year, straight-line depreciation would be applied in accordance with the 1981 U.S. tax, "Accelerated Cost Recovery System."

10. As a preliminary analysis study, inflation would affect all costs and revenues equally.

[5]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

DIRECTIONAL DRILLING DESCRIPTION

INTRODUCTION

Directional drilling is a technique by which a vertical or near vertical hole at the surface is accurately deviated to intercept a target located some distance away from the vertical path of the hole. In this case the target is a horizontal plane (i.e., the coalbed) (fig. 1). The directional hole is drilled in three phases. First, a small-diameter pilot hole is drilled in a smooth, continuous, nearly circular arc, to intercept the target coalbed horizontally. The hole is then reamed to provide for the installation of casing from the surface to a point within the coalbed and the casing is then cemented in place. Finally, small-diameter horizontal holes are drilled in the coalbed to gather gas (fig. 2). After the holes are drilled, a sump pump is installed to remove the water present in the coalbed. Subsequently, a water separator, compressor, meter house, and other equipment are installed at the surface to process the gas. The three-phase drilling explanation follows:

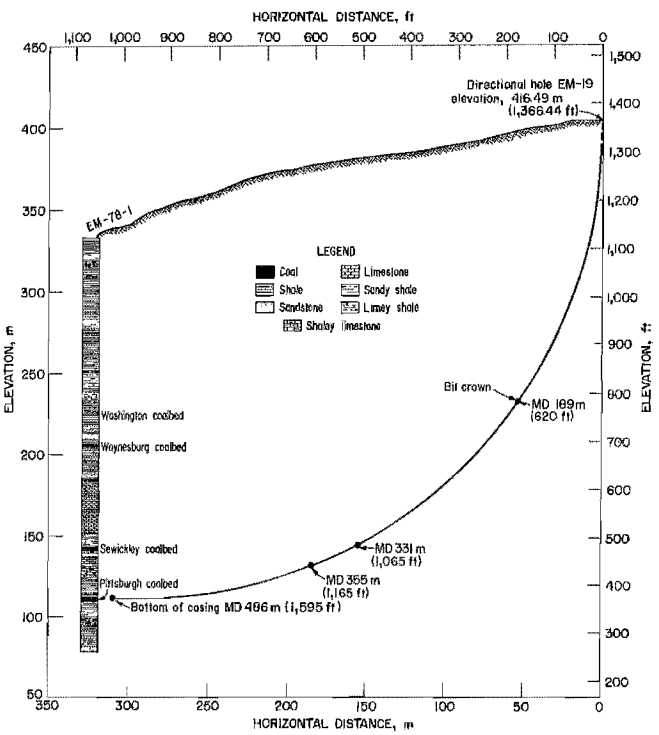

FIGURE 1. - Directional hole (6).

PILOT HOLE

Initially a 3-in-diam hole would be drilled to the coalbed using a downhole motor, small-diameter drill pipe, and a diamond bit. A surface pump, which would circulate fluid to the bottom of the hole, would provide power to the motor and also remove drill cuttings. The pilot hole would be deviated at a rate of 5° to 7° per 100 ft and borehole trajectory surveys would be taken at frequent intervals (10 to 20 ft) to ensure deviation control until the coalbed was intercepted.

REAMING

Reaming would be accomplished by rotary drilling, using a stinger assembly designed to follow the original arc of the pilot hole. A large-volume mud pump and either a polymer or bentonite type mud would be used to flush cuttings from the hole. After reaming, casing would be installed down to a point within the coalbed and cemented in place.

HORIZONTAL HOLES

The horizontal holes would be drilled using the same equipment and techniques used to drill the pilot hole. Three horizontal holes would be drilled from the bottom of the casing. One hole would be drilled straight ahead and the two additional holes would be sidetracked to the left and right by deviating laterally, at angles of 4° to 8° per 120 ft. The horizontal holes could be drilled to depths in excess of 3,000 ft.

WELL COMPLETION

The hole would be completed by the installation of a small-diameter submersible pump at the bottom of the casing. Water migrating through the coalbed would be removed by the pump as it reaches the borehole. Removal of the water reduces the formation pressure and establishes an unrestricted flow of gas to the surface. Subsequently, the gas well would be completed by installing wellhead equipment to monitor and process the gas.

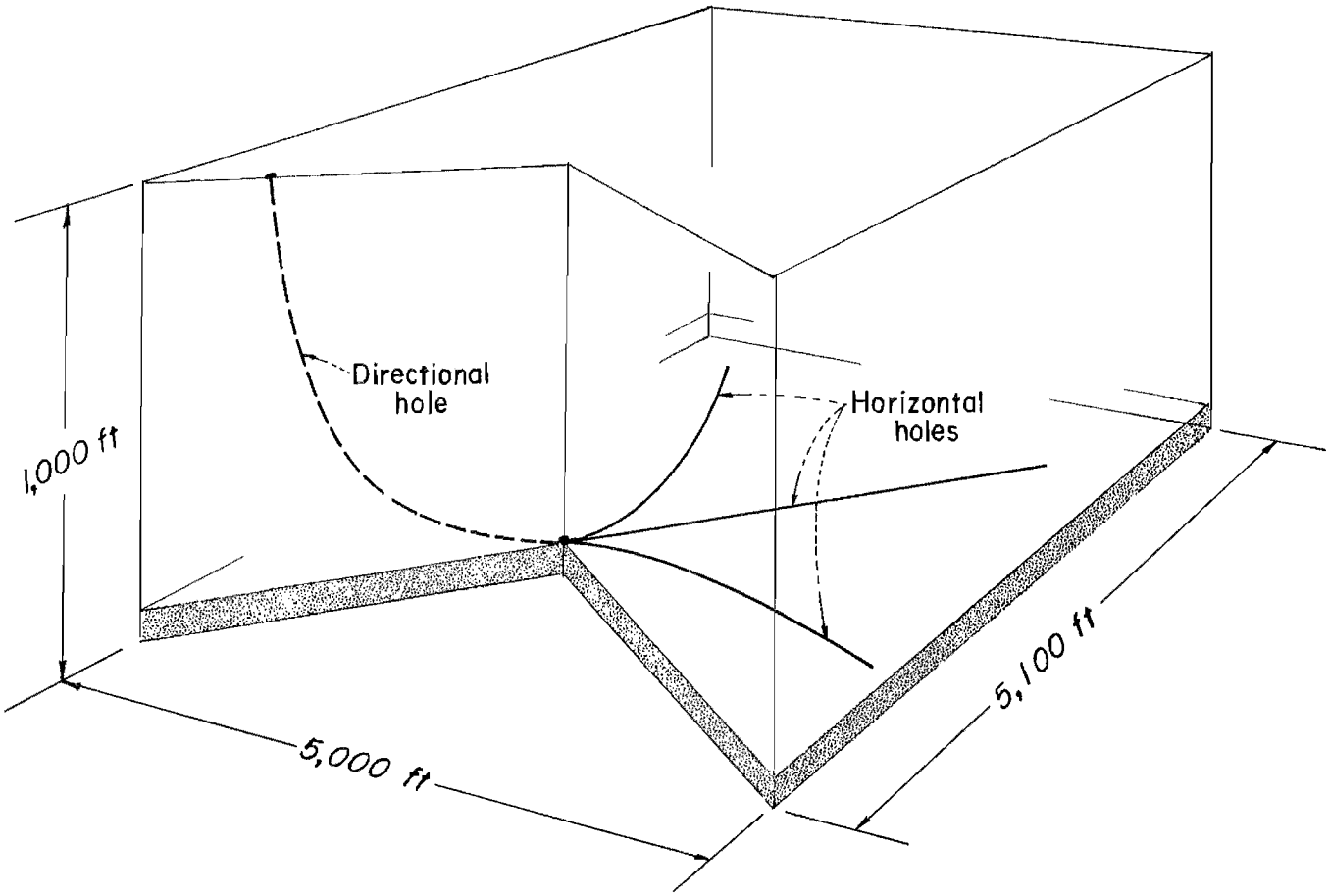

FIGURE 2. - Horizontal hole pattern.

METHANE GAS PRODUCTION

Previous methane drainage studies conducted in virgin areas of the Pittsburgh Coalbed have shown that horizontal holes will produce methane for long periods of time (3-4). Initial gas flows from the earlier studies varied from 200 to 259 ft^3/d per linear foot of horizontal hole. Stabilized gas flows after 1 yr of production varied between 130 and 170 ft^3/d linear foot of horizontal hole. At the end of a 5-yr period the gas flow had gradually declined to 96 ft^3/d per linear foot of horizontal hole. The average gas flow for the 5-yr interval was 124 ft^3/d per linear foot of horizontal hole. By using the data generated from the previous studies, it is possible to estimate the gas production of the directional hole at the Emerald Mine site. The total horizontal length of the directional hole within the coalbed at the Emerald Mine site was 7,555 ft. Therefore, yearly gas production would be 325 $MMft^3$ and total gas production after 5 yr of continuous operation would be 1,625 $MMft^3$.

BASIS FOR COST ANALYSIS

The total capital investment cost of this project was determined by compiling two cost schedules, one for the predrilling phase; the other for the drilling operations. Both are shown in the appendix (table A-1).

It was assumed that the gas producing company would provide personnel to plan, administer, engineer, purchase, and install surface equipment for the predrilling phase of the project, which was depreciated over 5 yr using the

straight-line method as shown in table A-2.

The costs of the contracted and rented drilling equipment and services except working capital detailed in table A-1, are classified as intangible drilling costs and as such they were not depreciable. These items were expensed in year 0 and subsequently carried forward as a loss against the first year in which there was revenue. The subsequent deduction of operating cost, depletion, and loss from revenues in years 1 and 2 resulted in negative taxable incomes (losses) that were carried forward until they were expended in year 3. Table A-4 reflects this accounting procedure.

The annual operating cost of this project was relatively small because it consisted primarily of routine maintenance and monitoring of equipment, which would not require a significant number of labor hours and repair parts. The items that make up the operating cost schedule are explained and costed in Table A-3.

The cash flow analysis, table A-4, and summary of discounted cash flows, table A-5, show the accounting entries and how they were used to arrive at the annual net cash flows, selling price per thousand cubic feet of gas, present value of annual and total cash flows, and net present value.

CONCLUSIONS

The findings of this report indicate that a capital investment in a directional hole methane drainage system from a gaseous coal reserve would be profitable based on the current and projected wellhead price of methane gas.

The maximum wellhead price of National Gas Policy Act section 103 gas, established by the Federal Energy Regulatory Commission for January 1, 1983, was $2.72 per thousand cubic feet.

The American Gas Association Terra Analysis of April 20, 1982, estimated that the price of section 103 gas in 1982 constant dollars after price deregulation on January 1, 1985, will be $4.36, subsequently decreasing to $4.13 in 1986 and $3.89 in 1987.

The wellhead selling price of methane gas at $2.05 per thousand cubic feet calculated in this report, which yields a rate of return on investment of 25 pct, indicates that directional hole drilling for gas recovery from coal warrants consideration as a current and future venture.

Also, as a result of methane gas drainage there could be a potential for increased coal production and decreased ventilation requirements.

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APPENDIX.--COST AND ANALYSIS TABLES

TABLE A-1. - Estimated capital investment (rounded to nearest $10)

PREDRILLING

Direct cost:	
Survey--1-acre site	$2,000
Access road (assume 1 mile), 15 ft wide, 8 in deep, red dog fill	3,300
Site preparation--clearing, grubbing 1 acre, dense timber	2,200
Surface gas meter	2,400
Surface water meter	650
Meter house--6 by 8 ft, fiberglass with heaters	2,250
Wellhead gas equipment--lines, control valves, water separator, flame arrester	3,000
Gas compressor--89 hp, 1 MMft^3/d capacity at 30-psig discharge	81,650
Power substation--1/2 mile from power source, 480 V, 3-phase with transformer stepdown to 220 and 110 V	9,000
80- by 20- by 6-ft mud pit--dozer work at $66/h for 8 h plus $120 plastic liner	650
8-ft fence around drill site--800 ft, 12-ft gate	8,500
Floodlights--5 wood poles, 400-W fixtures, 400 ft of wire, erected (material $2,680, labor $3,670)	6,350
Well casing:	
1,700 ft, 5-1/2-in OD, K-55, 15 lb/ft	11,710
450 ft, 9-5/8-in OD, K55, 36 lb/ft	6,590
Total casing pipe	18,300
Drilling mud and additives	67,050
Water for drilling mud--8,500 gal/d x 200 days at $0.0125/gal (includes hauling)	21,250
200-bbl water tanks--1 for 4 months and 1 for 7 months at $200/month each, haul permit $60, hauling $400 (round trip)	2,660
Truck-mounted drill rig--60,000-lb lift, equipped with 200-gal/min, 1,500-psig mud pump for 200 days	254,400
Drill pipe:	
Pilot hole and horizontal drilling--5,000 ft, 2-3/16-in OD, 10-ft lengths	45,050
Reaming--1,700 ft, 3-1/2-in OD, 30-ft lengths at $0.07/ft x 56 days plus after-use inspection of $1,590 and repair charge of $10,600	18,850
Total drill pipe	63,900
Reamer--2-stage bit, 8-3/4- and 12-in body at $159/5 days, $30 each additional day (15) plus tooth cutter bit at $2,188	3,430
Drill bits:	
Three 3-in diamond--$1,725 plus setting ($141 x 3)	5,600
Four 8-3/4-in diamond--$11,289 plus setting ($1,173 x 4)	49,850
Total drill bits	55,450
Fishing tools	9,390
Diesel fuel:	
Pilot hole plus horizontal drilling--82 days (25 + 57) x 3 shifts x 19 gal/shift	5,550
Reaming pilot hole--40 days x 3 shifts x 35 gal/shift (diesel tank furnished at no charge)	5,000
Total diesel fuel	10,550

TABLE A-1. - Estimated capital investment (rounded to nearest $10)--Continued

PREDRILLING--Continued

Direct cost--Continued	
Trailers:	
Office--8 by 36 ft (2 rooms, heat, air, 2 desks, planning table), 7 months at $150/month	$1,050
Storage--8 by 28 ft, heated, 7 months at $135/month	950
Haul charge for both $100/50 miles (round trip)	200
Total trailers	2,200
Portable toilet--rent, haulage, and service for 7 months at $50/month	350
Miscellaneous supplies:	
Car rental--6 cylinder, 4 door, stick shift, 232 days at $13.20/d	3,060
Truck rental--3/4 ton, 8-ft bed, 210 days at $13.20/d	2,770
Gasoline:	
Car--100 mi/d, 20 mi/gal, 232 days	1,400
Truck--150 mi/d, 12 mi/gal, 210 days	3,150
Total miscellaneous supplies	10,380
Area floodlights--five 400-W for 2,200 h and trailer lighting for 2,200 h, 7 months at $310/month	2,150
Total predrilling direct cost	643,410
Indirect cost: Administration, project superintendent, engineering, office, and overhead	64,340
Contingency	106,160
Total estimated predrilling costs	813,910

DRILLING

Direct cost:	
Labor:	
Drilling:	
Directional drilling engineer:	
Pilot hole, 35 days:	
1st day	850
34 days at $530/d	18,020
Subsistence--35 days at $60/d	2,100
Horizontal holes, 82 days:	
1st day	850
81 days at $530/d	42,930
Subsistence--82 days at $60/d	4,920
Total directional drilling engineer cost	69,670
Project superintendent, 7 months at $3,430/month	24,010
Rig supervisor, 7 months at $2,900/month	20,300
Driller-mechanic, 3 at $14.20/h x 6 h/d x 210 days	53,680
Driller helpers, 6 at $10.90/h x 8 h/d x 210 days	109,870
Casing installation, 16 h--mechanic and helper	400
Downhole pump installation, 16 h--mechanic and helper	400
Cement casing--1,700 ft and 450-ft collar, 34 centralizers	7,370
Total drilling labor	285,700
Maintenance: Driller-mechanic, 3 at $14.20/h x 2 h/d x 210 days	17,890
Total labor	303,590

TABLE A-1. - Estimated capital investment (rounded to nearest $10)--Continued

DRILLING--Continued

Direct cost--Continued	
Dyna-Drill equipment, parts and supplies, factory repair:	
Pilot hole drilling--stainless steel tool and motors:	
1st tool initial charge	$3,490
1st tool daily charge, 25 days at $16/d	400
2d tool daily charge, 28 days at $16/d	450
2d tool drilling charge, 7 days at $445/d	3,110
3d tool daily charge, 29 days at $16/d	460
3d tool drilling charge, 6 days at $445/d	2,670
Orienting sub--1, 35 days at $5/d	180
Motor--3, 35 days at $10/d	1,050
Horizontal drilling--stainless steel tools and motors:	
1st tool initial charge	3,490
1st tool daily charge, 70 days at $16/d	1,120
2d tool daily charge, 65 days at $16/d	1,040
2d tool drilling charge, 15 days at $445/d	6,680
3d tool daily charge, 65 days at $16/d	1,040
3d tool drilling charge, 15 days at $445/d	6,680
Orienting sub--1, 80 days at $5/d	400
Motor--3, 80 days at $10/d	2,400
Total equipment cost	34,660
Parts and supplies:	
2 dump valves, 80 days at $5/d	800
6 bent housings at $40 each	240
3 stainless steel motors, 115 days at $10/d	3,450
3 universal joints, 115 days at $6/d	2,070
2 sealed bearing assemblies, 115 days at $9/d	2,070
Orienting sub--1, 115 days at $5/d	580
Miscellaneous	16,250
Total parts and supplies cost	25,460
Factory repair:	
6 tools, pilot hole drilling; 15 tools, horizontal drilling, at $175 each	3,680
7 bearing units, pilot hole drilling; 18 bearing units, horizontal drilling, at $115 each	2,880
Air freight to factory and return, 46 pieces at $138 each	6,350
Total factory repair cost	12,910
Total Dyna-Drill costs	73,030
Geolograph services: Drilling rate and mud pump pressure gauges--installation, $470; rental, $5,524, 213 days	5,990
Geophysical logging: Neutron, density, gamma ray, and caliper log	1,910
Total drilling direct cost	384,520
Indirect cost: Administration, engineering, office, and overhead	38,450
Contingency	63,450
Fee	38,910
Total estimated drilling costs	525,330
Total estimated predrilling and drilling costs	1,339,240
Working capital	41,920
Estimated capital investment	1,381,160

TABLE A-2. - Annual depreciation schedule[1]

Tangible item:	Charge	Tangible item--Con.	Charge	Tangible item--Con.	Charge
Survey	$400	Power substation	$1,800	Drill bits	$11,090
Access road	660	Mud pit	130	Diesel fuel	2,110
Site preparation	440	Fence	1,700	Water for mud	4,250
Gas meter	480	Floodlights	1,270	Gasoline	910
Water meter	130	Well casing	3,660	Lighting	430
Meter house	450	Drilling mud	13,410	Indirect cost	12,870
Wellhead equipment	600	Drilling pipe (pilot hole)	9,010	Contingency	21,230
Gas compressor	16,330			Total	103,360

[1]In accordance with the 1981 U.S. tax, Accelerated Cost Recovery System, the cost of the tangible items would be depreciated in 5 yr using the straight-line method. The intangible short-term contracted and rented drilling equipment and services would not be eligible for depreciation (IRS Pub. 534).

TABLE A-3. - Annual estimated operating cost

Direct cost:	
Maintenance labor and equipment repair:	
Water pump--install year 1 and replace each year thereafter:	
Mechanic at $14.20/h x 16 h	$230
Helper at $10.90/h x 16 h	170
Surface equipment:	
Check gas compressor, wellhead equipment, gas and water meters--1 h/shift x 3 x $10.90/h x 365 days	11,940
Gas compressor--lubricate daily, oil change monthly, factory mechanic	2,760
Total maintenance labor	15,100
Wellhead and meter house equipment repair--10 pct of maintenance labor	1,510
Total maintenance labor and equipment repair	16,610
Equipment and supplies:	
Downhole water pump and accessories	7,810
Drill rig to replace water pump--1-day rental	680
Periodic repairs and overhaul compressor once per year	2,750
Wellhead and meter house--equal to labor repair	1,510
Total equipment and supplies	12,750
Power:	
Downhole water pump--50 pct operating time, 4,380 h/yr x 2.25 kW x $0.055/kW·h	540
Wellhead gas feed to compressor--917 ft^3/h x 8,322 h/yr x $2.05/M ft^3	15,640
Total power	16,180
Payroll overhead--40 pct of maintenance labor and equipment repair	6,640
Total direct cost	52,180
Indirect cost: 15 pct of maintenance labor, equipment repair, and equipment and supplies	4,400
Fixed cost:[1]	
Depreciation (table A-2)	103,360
Property insurance--1.5 pct of depreciable items	7,750
Total fixed cost	111,110
Estimated annual operating cost	167,690

[1]Pennsylvania does not levy a mining property tax.

TABLE A-4. - Cash flow analysis

(Selling price per thousand cubic feet of gas--$650,590/317,360 M ft^3 = $2.05)

Year	0	1	2	3	4	5
Revenue	NAp	$650,590	$650,590	$650,590	$650,590	$650,590
Operating cost	NAp	-167,690	-167,690	-167,690	-167,690	-167,690
Intangible drilling cost[1]	-$822,440	NAp	NAp	NAp	NAp	NAp
Gross profit	-822,440	482,900	482,900	482,900	482,900	482,900
Depletion[2]	NAp	-117,110	-104,090	-97,590	-97,590	-97,590
Loss forward	NAp	-822,440	-456,650	-77,840	NAp	NAp
Taxable income	-822,440	-456,650	-77,840	307,470	385,310	385,310
PA State tax (0.105)	NAp	0	0	-32,280	-40,460	-40,460
Federal tax base	NAp	0	0	275,190	344,850	344,850
Federal tax (0.46)	NAp	0	0	-126,590	-158,630	-158,630
Net before investment tax credit	NAp	0	0	148,600	186,220	186,220
Investment tax credit[3]	NAp	0	0	+51,680	NAp	NAp
Net income	-822,440	-456,650	-77,840	200,280	186,220	186,220
Depreciation	NAp	+103,360	+103,360	+103,360	+103,360	+103,360
Depletion	NAp	+117,110	+104,090	+97,590	+97,590	+97,590
Loss forward	NAp	+822,440	+456,650	+77,840	NAp	NAp
Cash flow	-822,440	586,260	586,260	479,070	387,170	387,170
Tangible capital cost[4]	-516,800	NAp	NAp	NAp	NAp	NAp
Working capital[5]	-41,920	NAp	NAp	NAp	NAp	+41,920
Net cash flow	[6]-1,381,160	586,260	586,260	479,070	387,170	429,090

NAp Not applicable.

[1]Nondepreciable items from predrilling and drilling costs, table A-1.

[2]Internal Revenue Service allowable depletion rates for 1982 at 18 pct, 1983 at 16 pct, 1984 following at 15 pct.

[3]10 pct of depreciable items in accordance with Internal Revenue Service, 1982, Form 3468.

[4]Depreciable items times 5 yr (from table A-2).

[5]Equal to 3 months' operating cost.

[6]Total capital investment from table A-1.

TABLE A-5. - Summary of discounted cash flows

Year	Capital investment	Net cash flow	Present worth factor at 25 pct	Present value of cash flows
0	$1,381,160	-$1,381,160	1.00	-$1,381,960
1	0	586,260	.8000	469,010
2	0	586,260	.6400	375,210
3	0	479,070	.5120	245,280
4	0	387,170	.4096	158,580
5	0	429,090	.3277	140,610
Present value of cash flows				$1,388,690
Net present value				[1]7,530

[1]A net present value of zero would indicate a discounted cash flow rate of return of exactly 25 pct. The true rate of return is 25.29 pct.

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